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Repeatless: the use of digital technology to extend the possibilities of printed textile design

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ABSTRACT

This paper describes an original, interdisciplinary model by which repeatless patterns can be generated dynamically in real time and streamed to a digital printer. The model produces designs that have a negligible probability of repeating. Their underlying structure is based on cellular automata, modeling traditional pattern design methods of arranging motifs or other design elements. The motifs within the pattern respond in real-time to each other, creating a composition of indefinite length. This is sent to a digital fabric printer as it is being generated, exploiting the technology in an entirely novel fashion.

Keywords: generative design, digital fabric printing, printed textile design, surface pattern design, non-repeating pattern, programming, cellular automata, complexity, Processing (computer programming language)

1. Introduction

Pre-digital mass-production textile printing technologies mechanically transfer the same design over and over again down the entire length of the substrate. Whether printed by block, copper roller or rotary screen, repeat patterns must loop identically, and cannot be altered without the printer being stopped and reconfigured. Rotary screen-printing remains the prevalent method, but whilst digital fabric printing is responsible for a relatively small percentage of the total production, its use is growing quickly [1]. A number of the benefits of digital printing over previous technologies are currently being utilized by the textile industry, including the simplification of the workflow in setting up a print [2] and feasibility of short runs [3]. In turn, designers are appreciative of the ease by which complex imagery may be transferred to fabric and the limitless number of colours a design may now feature [4].

Digital technology has further potential to extend the design and manufacturing of printed textiles. The possibility that digital fabric printing could remove the need for a repeating pattern has been identified [5] and subsequent proposals have considered the implications of the technology on pattern design [6][7][8]. However, the integration of the design and print process that digital technology has provided offers further opportunities to break new ground and it is one of these that this paper will focus on.

Currently, the content of a design is finalised before being sent to a digital fabric printer. The data from which such a printer works does not alter once the print has started, regardless of whether it is in repeat or not. How the design appears on fabric may be determined by digital information rather than a physical mechanism such the etched holes in a rotary screen, but at present, both are pre-determined. It is suggested that digital fabric printing technology could allow a design to change dynamically as it is being printed. The research outlined in this paper demonstrates a novel method of writing a software application that generates a constantly evolving design. This populates a virtual space with a range of motifs or other design elements that respond dynamically to each other over time using a mathematical system. There is an input of new elements in each cycle of the evolution and the output is repeatless; an endlessly changing pattern that can be streamed to a digital printer to be transferred onto any length of fabric or other substrate.

2. Generating non-repeating pattern dynamically using cellular automata

It is proposed that a generative design process be used to produce the endlessly changing pattern. Such a process can be defined as ‘the generation of designs by a set of rules or an algorithm, usually using computers’ [9]. Generative methods have been employed in other design disciplines such as architecture [10] and graphics [11], where outcomes are digitally “grown” or “evolved”. In comparison, this idea has been relatively unexploited in textiles although research has considered how randomness could create non-repeating design [12], interactive design [13], animated pattern [14] and tapestry-based applications [15][16].

In order to produce the generative designs, some form of model is required. It is at this point that the research becomes interdisciplinary, bridging textile design and mathematics. A printed textile design is composed of a number of different elements. These may be very simple (a spot or a stripe, for example) or a much more complex motif (an intricate drawing of a flower, for instance). Whatever the content, the arrangement of these components within the design is crucial. In searching for a method to control this arrangement, it was decided to use cellular automata, mathematical models that allow the components of a system to interact with each other over time.

> ‘A cellular automaton consists of a regular uniform lattice (“array”)… with a discrete variable at each site (“cell”)… [It] evolves in discrete time steps, with the value of the variable at one site being affected by the values of variables at sites in its “neighbourhood” on the previous time step… according to a definite set of “local rules”.’[17]

In this instance, rules are devised that model the techniques of a printed textile designer. When creating an all-over pattern, a designer will generally ensure that the eye can roam freely over it, composing the motifs within it so no one part of the design stands out. Without this balance, areas of the design will tend to dominate, often where there appears to be order.

> ‘This problem, known as “tracking” within the surface design industry, where an unintentional stripe or diagonal has been created, can be resolved by scattering copies or variations of noticeable elements in a design in such a way that they appear to be randomly placed and equally balanced with other similar motifs or coloured areas… A balanced distribution of negative space is also critical.’[18]

Methods of configuring the elements in a design so tracking is avoided and a balanced design can be achieved have been developed as cellular automata. These form the basis of the underlying structure for the programming that produces the generative designs.

In addition to thinking about the creative design process, it is also important to locate the research in the context of the printed textile industry and, by extension, of the requirements of the consumer. To achieve this, the structure that would subsequently be used to underpin the generative process was framed by the following principles:

i. The design must remain seamless, flowing down the fabric without any apparent break or join. Being able to use any part of the fabric as part of a garment, soft furnishing or other product avoids wastage. Industry expects this of a repeat design; a repeatless one should offer the same quality.

ii. The design should be an identifiable pattern, even if it does not repeat. As it has been proposed that '[it] seems that we are instinctively drawn to designs that mimic the rhythms found in nature' [19], it is suggested that the arrangement of elements in the design should reflect this tradition. Whilst a fabric printed with a repeatless design could be used for one-off or bespoke products, the facility to do a long print run would allow it to be used in mass production. The number of motifs within the design, their composition and their colour can be limited to ensure that any two sections of the fabric, regardless of their distance apart, can be seen to have a visual relationship.

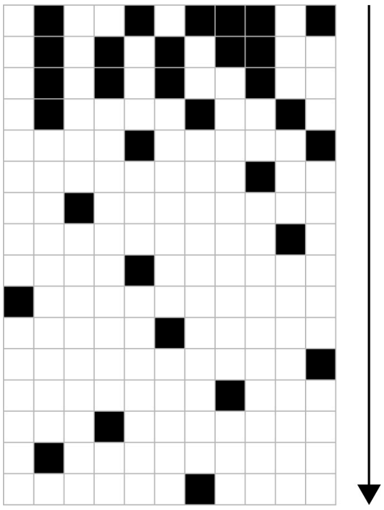
iii. The design should be able to feature any type of style or content. Quite deliberately, the code featured in this paper uses existing imagery to generate the final design. It would be perfectly possible to rewrite the code to generate its own visual content rather than work with preselected motifs. (Indeed, it is intended that subsequent research will do this.) However, in order that the repeatless process can be widely applicable to industry, it must work with any type of imagery. Therefore, the system works any visual source material, whether hand drawn, painted, photographic or digital in origin.

These criteria and the cellular automata are then used to develop a series of algorithms. In turn, these form the foundation from which to write the code that produces the repeatless designs. The programming is done using Processing, 'a text programming language specifically designed to generate and modify images' [20].

Prior to running the programme, the individual motifs and other visual elements that will form the content of the final design are placed into a source folder. The nature of these components is entirely flexible (see iii above) but could, for example, be based around a particular style the designer has been requested to work with.

The generative design process begins by establishing a two dimensional grid of square cells. The number of cells and their dimensions can be varied to suit the style of the final design and the width of the fabric it will be printed on. Each cell has a small amount of numeric data assigned to it, including whether or not it is full. A full cell will contain a motif or other visual element. In the context of cellular automata and other complex systems, analogies are often made with biological terms. In this case, the data in the cell can be thought of as the set of genes it contains and be termed the cell's genotype. Further on in the generative process and within a second grid, the genotype will be used to provide the visual characteristics of the design element that will occupy the full cell. These characteristics can be termed as the cell's phenotype [21].

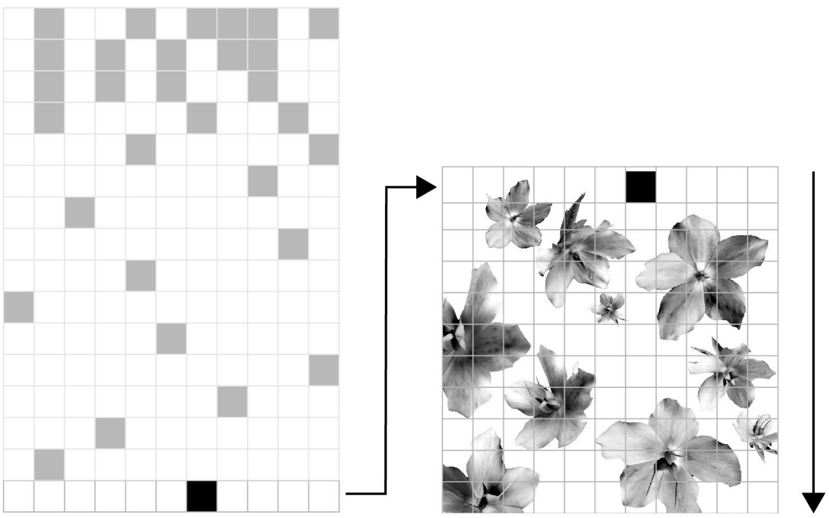
At each time step, the full cells interact in accordance with the rules of a number of different cellular automata. Once the interaction is complete, the contents of the first grid are updated and shifted down one row. By the time the cells reach the bottom row of the grid, they will have been subject to the series of cellular automata outlined in the following paragraph. The bottom row of this first, genotype grid becomes the top row of a new, second grid; it is here that the genotype data is converted to the corresponding phenotype characteristics. In other words, the numeric information that comes out of the first grid becomes visual information (that is, the design) in the second.



As the cells move down the first gird, the actions of a series of cellular automata transform them from a random arrangement to one that models traditional motif composition in printed textile design.

Figure 1: The first, genotype grid

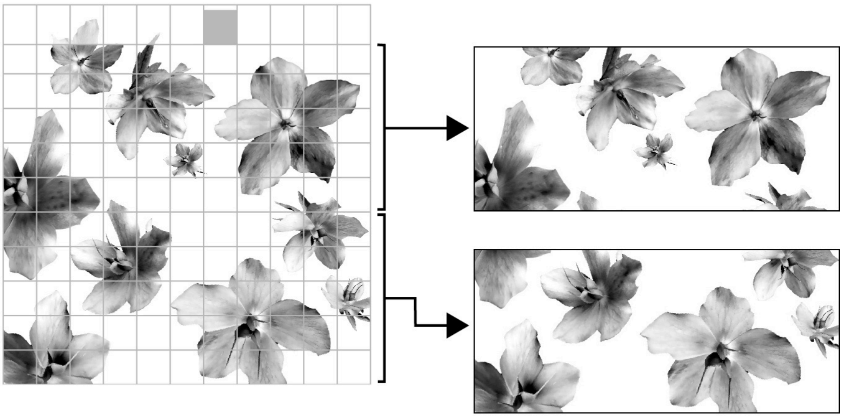
Initially, some of the cells in the first rows of the first grid are randomly filled. As the cells shift down the grid, the cellular automata come into play, based around the principles previously outlined of keeping the eye roaming freely round the design (Figure 1). Full cells are moved or emptied to avoid forming obvious stripes or diagonals. Movement is magnified when nearby cells have similar visual content. The data that determines the scale of the motifs that will subsequently be used is balanced in such a way as to achieve a good spread of size across the design; large motifs favour being placed further apart. If too big a gap appears between motifs, or one with an obvious horizontal or vertical shape, an empty cell within the gap is filled to rebalance the design. Once into the second grid, the full cell data is used to position and scale the motifs or other visual elements that were originally placed in the source folder. As this phenotype grid moves down, the cells become populated by the motifs, and the final repeatless design appears (Figure 2).



Once they reach the bottom of the first grid, the cells are transferred to the top of the second grid. The data within them is converted to imagery as they move down.

Figure 2: The second, phenotype grid

Rather than allow this design to grow indefinitely, it is saved as a series of sequential images. Whatever the size of the final pattern, dividing it into a series of images of finite size makes it much easier for a digital system to process. The top edge of any one of these images flows seamlessly into the bottom edge of the next image. These images can be sent in turn to a digital printer, which could print them one after the other onto the fabric as a repeatless pattern.



The second grid is saved section by section as a series of images, each of which fits with no apparent join into the ones before and after it. These images are streamed to a digital fabric printer.

Figure 3: Sending the repeatless design to print

The final outcome is a pattern design that can be of any length. The design will have the visual characteristics of the motifs or other imagery placed in the source folder. The code that arranges these elements does so with models that tap into the rich history of printed textile design. The exploitation of digital technology in the way outlined here allows a new development; printed pattern that never repeats.

3. Conclusions

This paper proposes a new way of designing and printing pattern onto textiles or other substrates using digital technology. This involves a generative process, where a programme written in Processing arranges a series of motifs or other elements to create a final design. The programme uses cellular automata that have been developed from the methods employed by printed textile designers to ensure that a pattern spreads smoothly over the surface it decorates. It can be used with any sort of visual source material. The output design is seamless and repeatless, but remains identifiably pattern.

The programme works in three stages. At the first genotype stage, a grid of cells is populated with a degree of randomness. The cells interact dynamically using the cellular automata rules that model the pattern design process. Numerical information from this stage is used in the next, phenotype stage, at which point the data is converted to pattern using the imagery from the source folder. In the third stage, the final repeatless design is saved section by section to be streamed to a digital fabric printer.

Prior to digital technology, printing was essentially the ability to reproduce the same image (or text) over and over again. Much of the initial use of digital technology within the textile industry has focused on that which screen printing or other fabric printing methods can not easily do; work with photographic imagery, for example, or print with unlimited colour or scale. The research here firstly identifies that there is something fundamentally different about digital fabric printing in relation to its forerunners. It does not have to work from static information. It can print a design that changes as it is being printed. Secondly, it demonstrates that digital technology can provide the content with which to do this, creating a design that can change as it is being printed.

Seen individually, digital design and digital printing technology present a large number of new possibilities for the printed textile industry. This paper shows a way that practice-led research can integrate them and offer a method to shift the paradigms of what pattern is and the way it can be reproduced.

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